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# Changes in CCCM SW and LW Irradiances with New Versions of Cloud Inputs and Algorithm Changes


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# CCCM Flux Computations

- The CCCM flux algorithm takes cloud information from CALIPSO, CloudSat, and MODIS for better describing cloud vertical profiles and optical properties (Kato et al. 2011).
- RelB CCCM product was released in 2011, and development of RelD CCCM product is ongoing with new versions of CERES (Ed4), MODIS (Ed5), CALIPSO (V4), and CloudSat (R05).

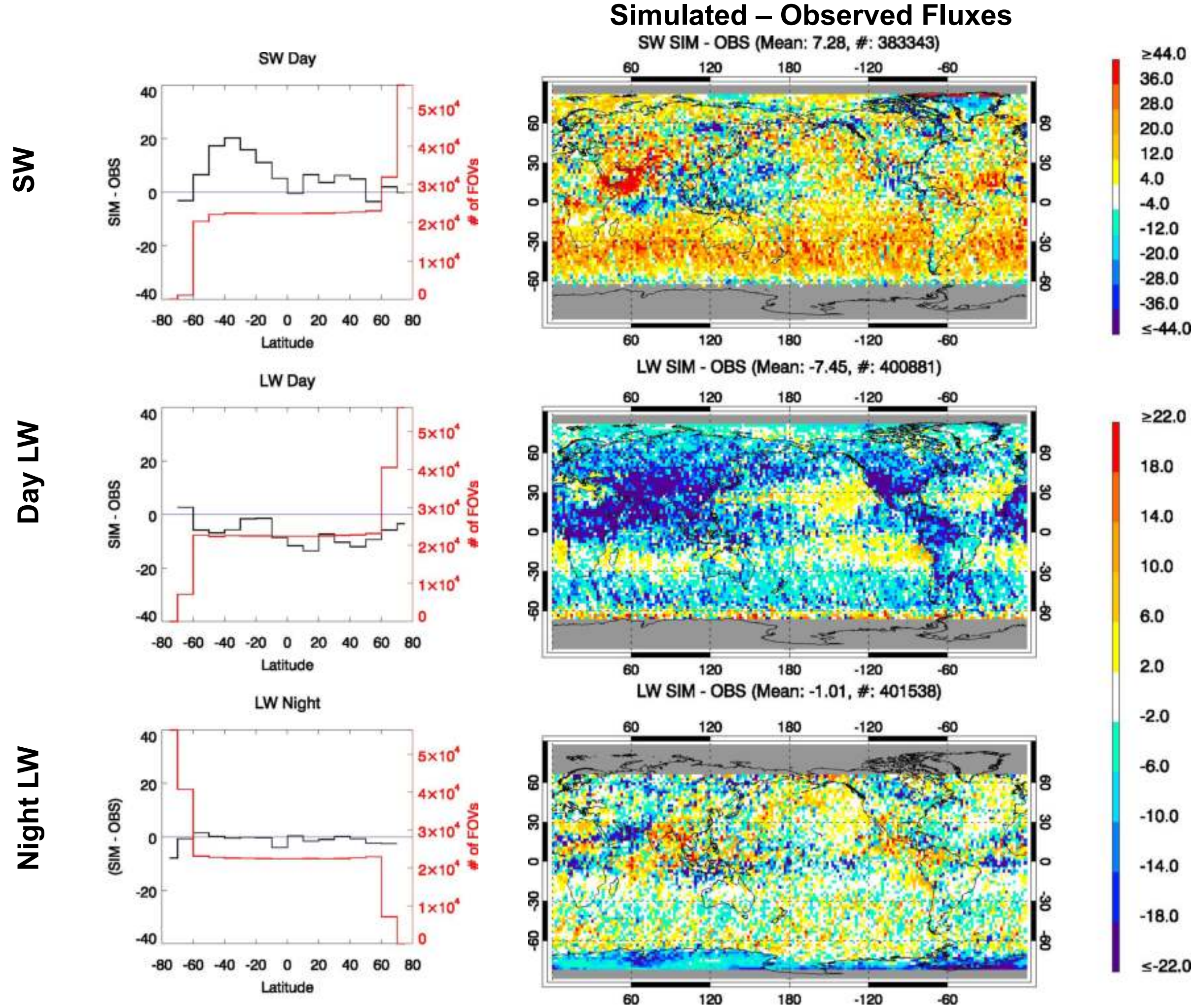
# Objective

- We examine how much fluxes are changed from RelB to RelD, associated with implementing new datasets and algorithm improvements.

# Input Parameters Used For RelB and RelD CCCM Flux Computations

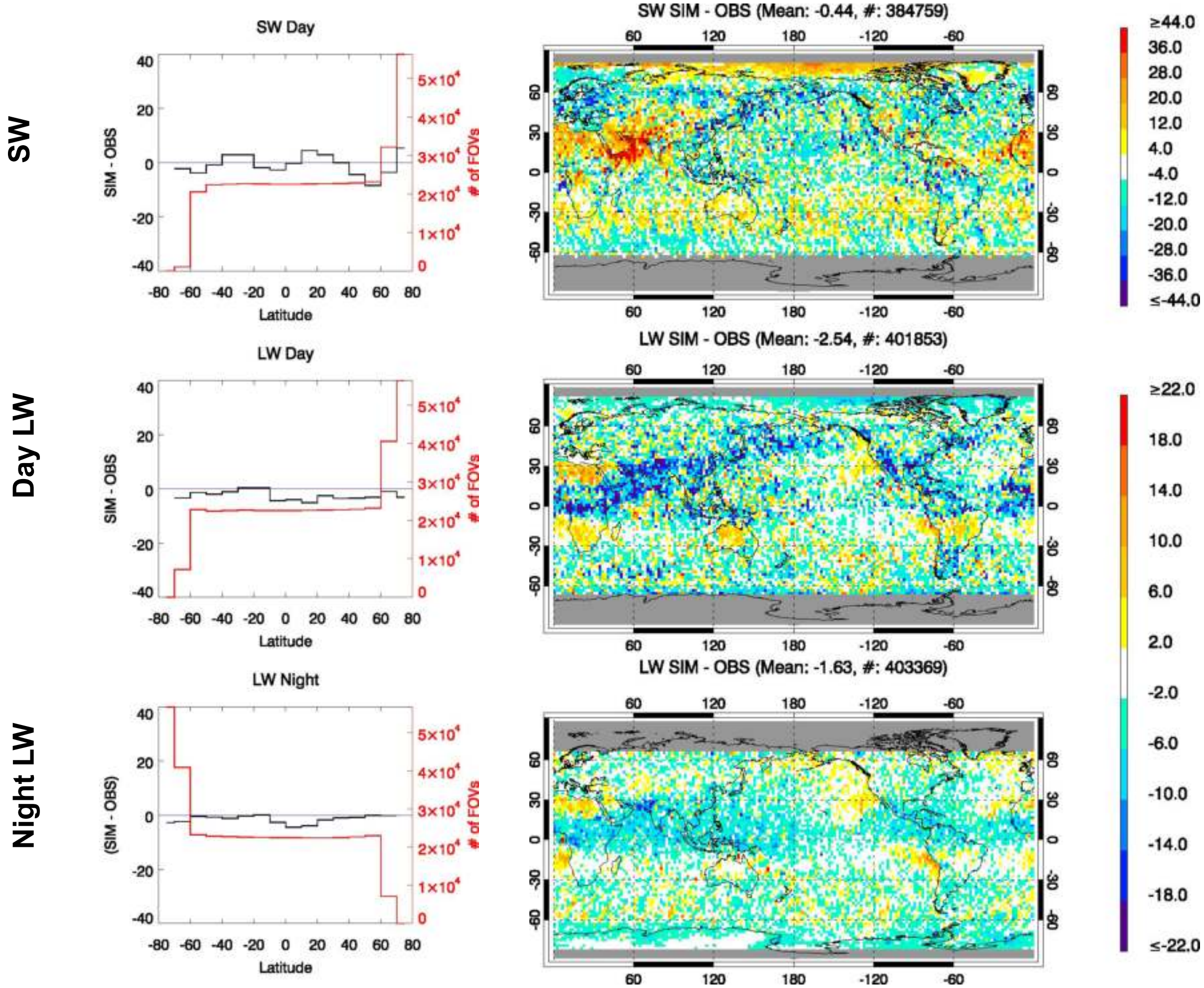
| | Release B (RelB) | Release D (RelD) |
|---|---|---|
| MODIS Clouds | Beta Edition 3 (Revised version of Ed2)<br>(Smooth hexagonal single habit ice model) | Evolving Edition 5<br>(Two-habit ice model) |
| CALIPSO | V3 | V4<br>Also water clouds below 4 km detected with non-single shots are excluded. |
| CloudSat<br>2B-CWC<br>2B-CLDCLASS | Release 4 | Release 5<br>(Liquid 2B-CWC has been significantly changed but not the ice phase) |
| CloudSat 2C-ICE | Not used | Implemented, and used as a first choice |
| MATCH | Daily (MOD Collection 05) | Ed4 Hourly |
| Solar Constant | 1365 W $m^{-2}$ Fixed Value | SOLCE Database (~ 1361 W $m^{-2}$ for July 2008) |
| Sea/Ice Albedo | Climatology | Pre-Processed Surface Albedo History (SAH) Map |

# Simulated Flux Biases (= Sim – Obs) in CCCM RelB (July 2008)



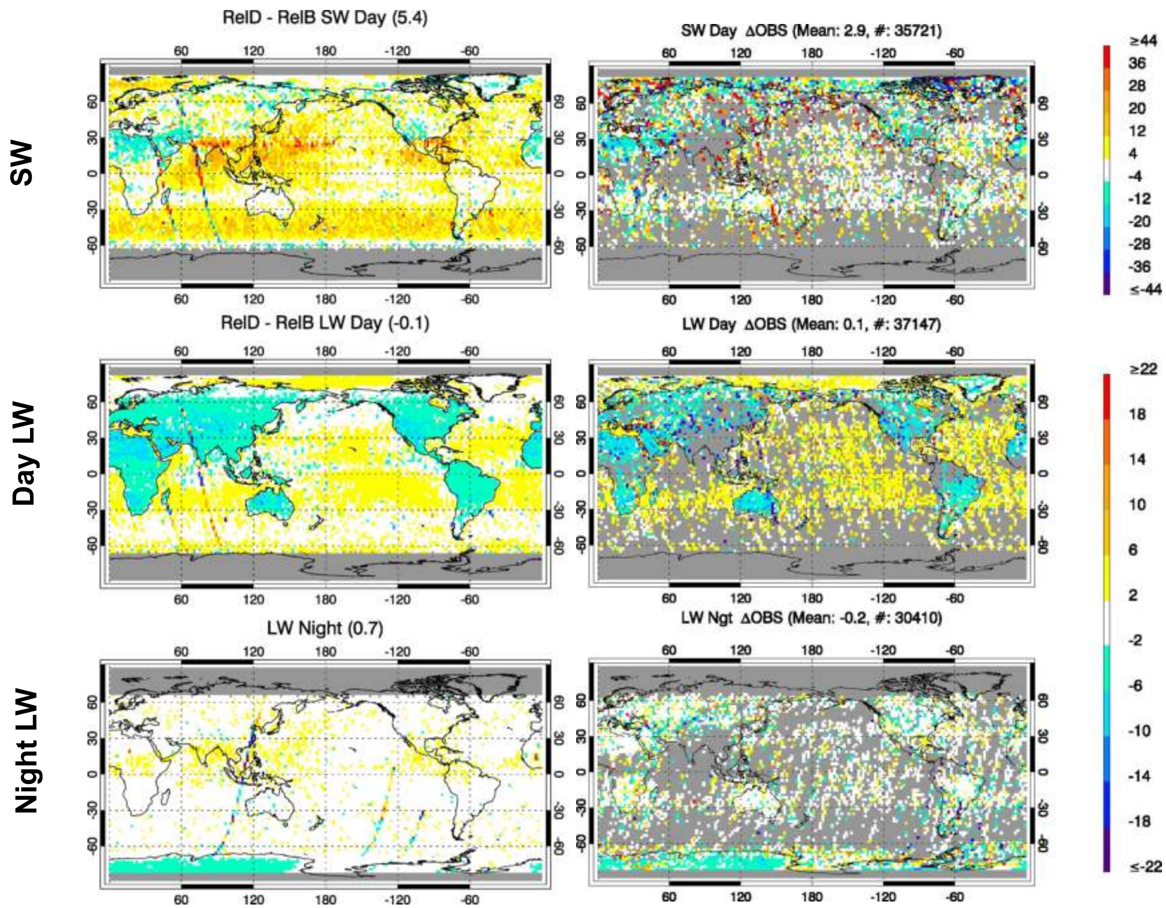
# Simulated Flux Biases in CCCM RelD (Ongoing Process) (July 2008)

**Simulated – Observed Fluxes**



# CERES-Derived (Observed) Fluxes between RelB and RelD CCCM Products (July 2008)

**RelD – RelB (All Sky)** **RelD – RelB (Clear Sky)**




- Note that CERES fluxes in RelB and RelD CCCM products are different from those in SSF Ed2 or Ed4 products since Ed3 (revised Ed2) MODIS clouds were used for selecting Ed2 ADM types in RelB, and Ed5 MODIS clouds were used for selecting Ed4 ADM types in RelD.
- CCCM product only includes CERES footprints with nadir views, unlike SSF products.
- Observed (CERES-derived) SW fluxes are increased by 5.4 W m$^{-2}$ from RelB to RelD.

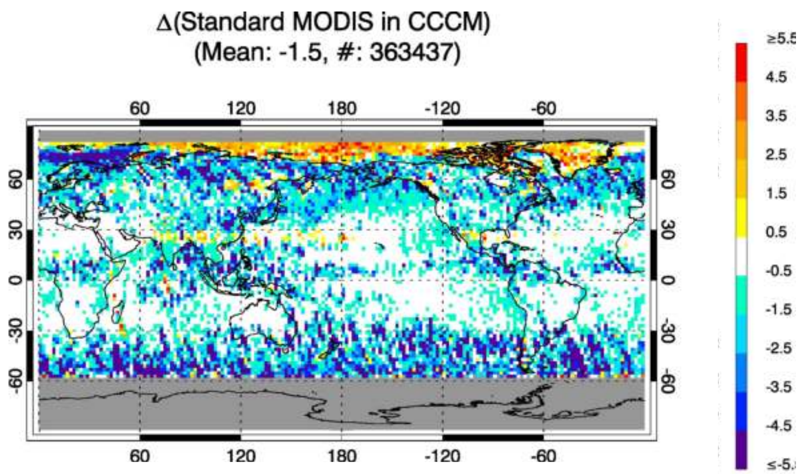
## Changes of Simulation Biases from RelB to RelD for July 2008

| W $m^{-2}$ | RelB | | | RelD | | |
|---|---|---|---|---|---|---|
| | Obs | Sim | Sim – Obs (Mean±RMSD) | Obs | Sim | Sim – Obs (Mean±RMSD) |
| SW | 222.2 | 229.5 | +7.28 ± 46.71 | 227.6 (+5.4) | 227.2 (–2.3) | –0.44 ± 35.97 (+7.7) |
| Day LW | 251.6 | 244.1 | –7.45 ± 20.07 | 251.5 (–0.1) | 249.0 (+4.9) | –2.54 ± 14.87 (–4.9) |
| Night LW | 242.0 | 241.0 | –1.01 ± 19.92 | 242.7 (+0.7) | 241.1 (+0.1) | –1.63 ± 8.94 (–0.6) |

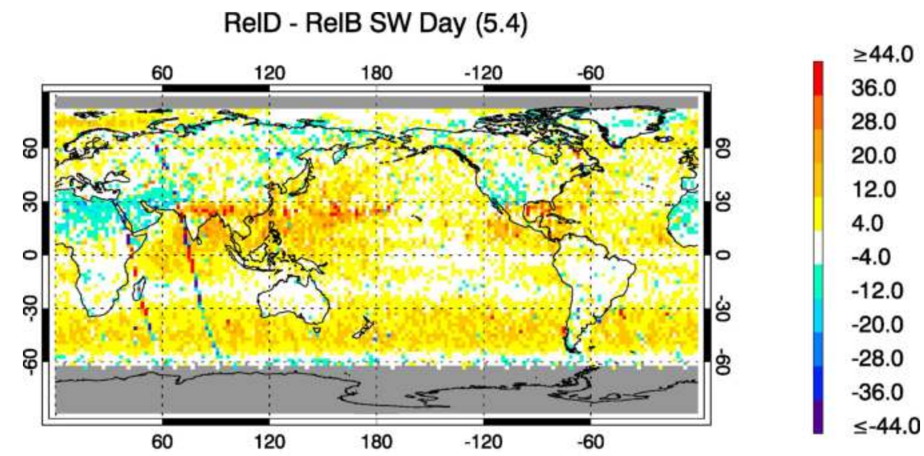
- Both mean biases and RMSDs are improved in RelD, compared to RelB.
- From RelB to RelD, SW observed fluxes are increased by 5.4 W $m^{-2}$, and this explains 70% of changes of SW flux biases (= simulated – observed fluxes). In addition, SW fluxes are decreased by 2.3 W $m^{-2}$, resulting in decrease of SW biases by 7.7 W $m^{-2}$.
- Simulated daytime LW fluxes are increased by 4.9 W $m^{-2}$.

# Changes in Cloud Optical Depths and CERES-Derived SW fluxes from RelB to RelD

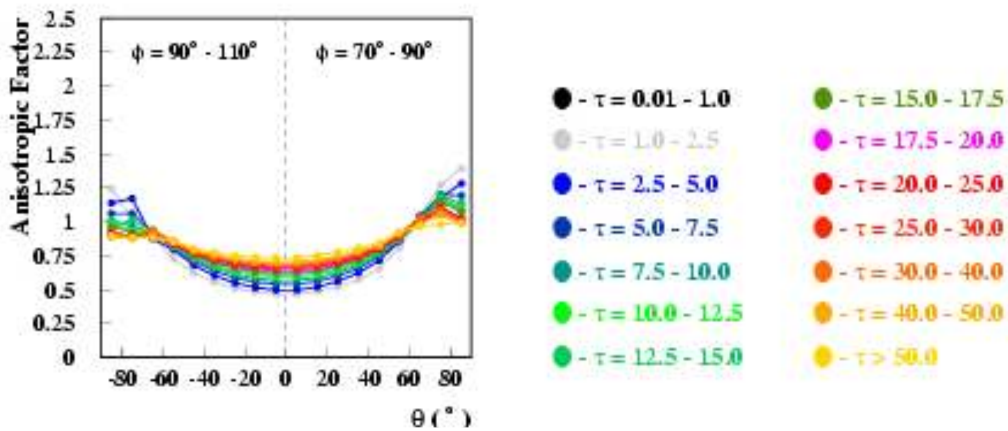
Daytime cloud optical depth changes
$\boldsymbol{f_c} \ \mathbf{exp}\left[\overline{\boldsymbol{ln\ \tau_c}}\right]$ (Ed3 → Ed5)




Changes of CERES-derived SW fluxes




As the cloud optical depth is smaller, derived SW flux is larger because ADM is smaller at nadir views.



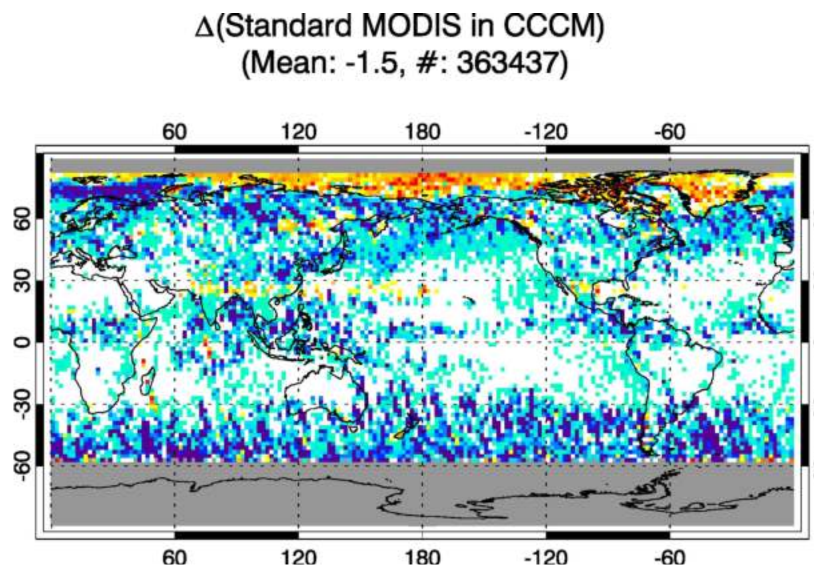

fc=99.9-100%
Water clouds
SZA=70-80deg
RAA=70-90deg

# Causes of Simulated Flux Changes between RelB and RelD CCCM

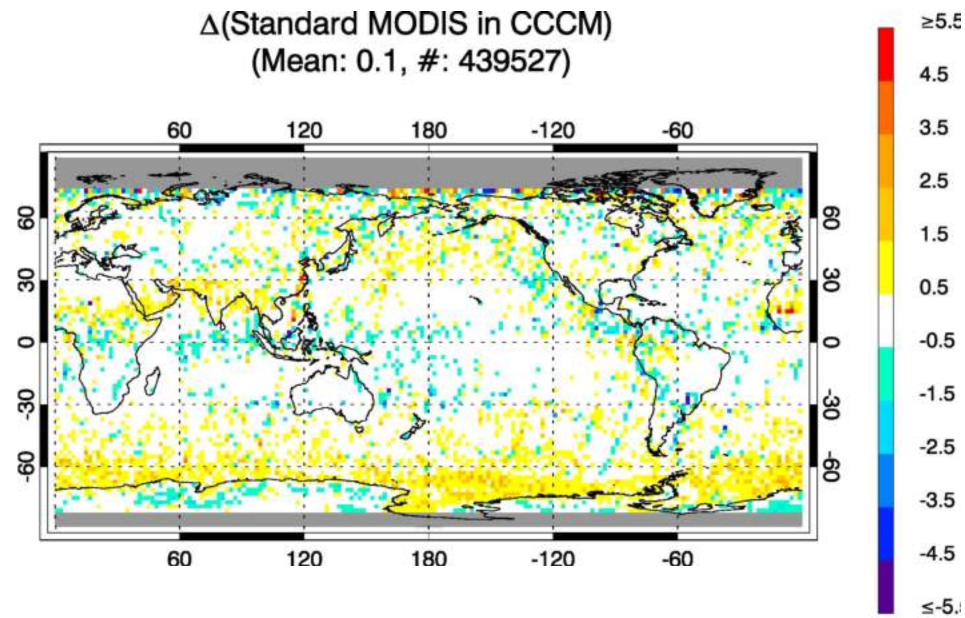
| | |
|---|---|
| Cloud Input Changes | 1) Changes in MODIS cloud optical depths (and ice scattering model)<br>2) Reduction of CC cloud covers due to exclusion of CALIPSO water clouds detected with non-single shots |
| Cloud Algorithm Changes | 1) New nighttime IR constraining method of merged cloud profiles<br>2) Different cloud phase assignment using temperature, CALIPSO phase, 2C-ICE |

## Changes in MODIS Cloud Optical Depths from RelB to RelD

Daytime cloud optical depth changes
$\boldsymbol{f_c} \ \mathbf{exp}\left[\overline{\boldsymbol{ln\ \tau_c}}\right]$ (Ed3 → Ed5)



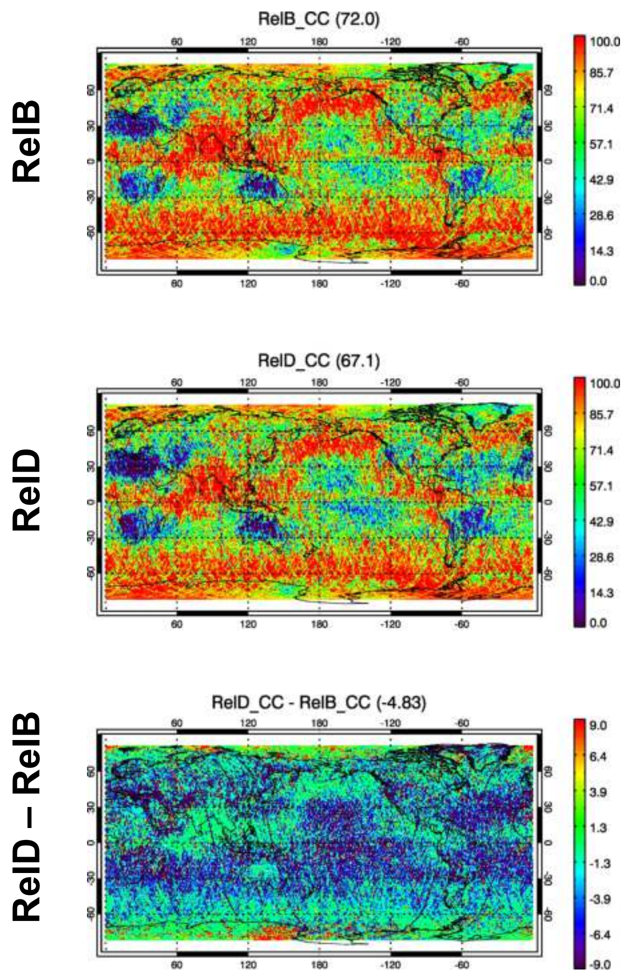

Nighttime Cloud optical depth changes
$\boldsymbol{f_c} \ \mathbf{exp}\left[\overline{\boldsymbol{ln\ \tau_c}}\right]$ (Ed3 → Ed5)




- Daytime MODIS cloud optical depths are significantly decreased in RelD.

## Changes in CALIPSO-CloudSat (CC) Cloud Area

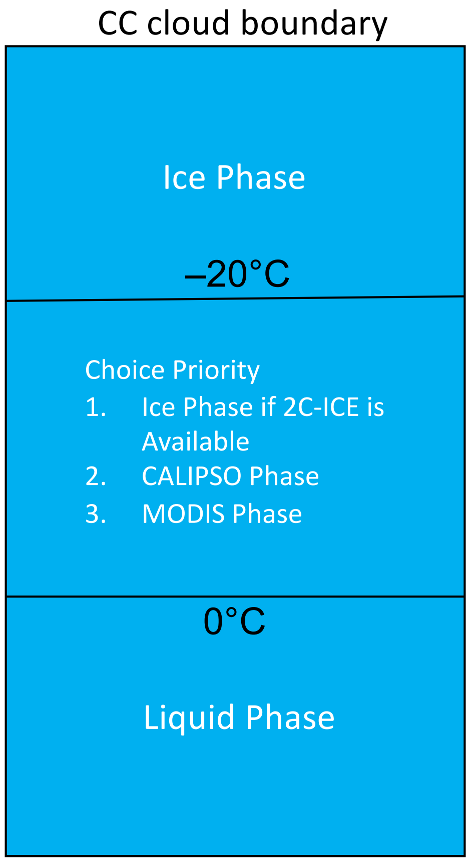
**Day+Night**




- For flux computations, we determine whether the area is clear or not based on CALIPSO-CloudSat detections.
- In RelD, water clouds below 4 km detected with non-single CALIPSO lidar beam are screened out. This is because water particles generate strong lidar signals and affect surrounding pixels if spatial averaging is taken, causing over-detections of water clouds.
- By excluding water clouds with non-single shots, CC cloud areas are largely reduced over broken cloud regions, located between overcast and clear regions, which decreases SW fluxes and increase LW fluxes.

(July 2008)

**Step1: Determine cloud phase for each vertical grid bin Using Temperature and CALIPSO Phase**



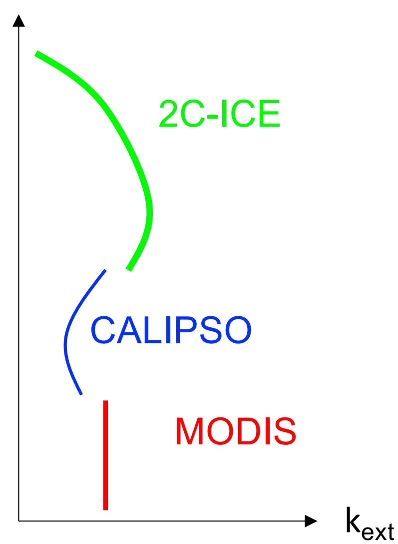

**Step 2: Merging Cloud Profiles Using CALIPSO, CloudSat, and MODIS**

<u>Ice Phase</u>

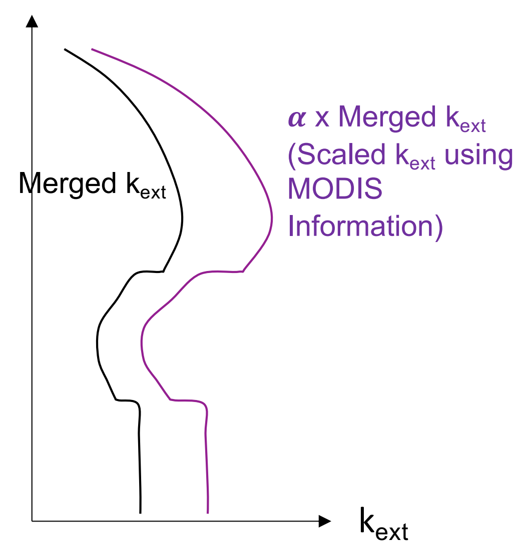
1. 2C-ICE
2. CALIPSO
3. CloudSat
4. MODIS

<u>Water Phase</u>

1. CALIPSO
2. CloudSat
3. MODIS




**Step 3: Normalizing the merged cloud extinction profile (or obtaining a scaling factor $\alpha$) with MODIS information**



## Normalizing Merged Cloud Extinction Profiles with MODIS Information
## [A scaling Factor ($\alpha$) applied to the merged cloud profile]

- When MODIS cloud optical depth is derived from visible channels (SZA ≤ 82°) (Kato et al., 2011)

$$\tau_M(1 - g(r_M)) = \alpha \sum_{i=1}^{n} k_{CCM}(i)\Delta z_i \,(1 - g(r_{CCM}(i)))$$

MODIS Scaled Cloud Optical Depth

$\alpha$ is a scaling factor to reproduce MODIS-equivalent scaled optical depth from the merged extinction profile ($k_{CCM}(i)$).

This normalization works well when the MODIS cloud optical depth is retrieved from VIS channel.

- When MODIS cloud optical depth is derived from infrared channels (SZA > 82°) – Added in RelD

$$\varepsilon_{11} B(T_{skin}) \exp(-\tau_M) + (1 - \exp(-\tau_M)) B(T_{eff,MODIS})$$

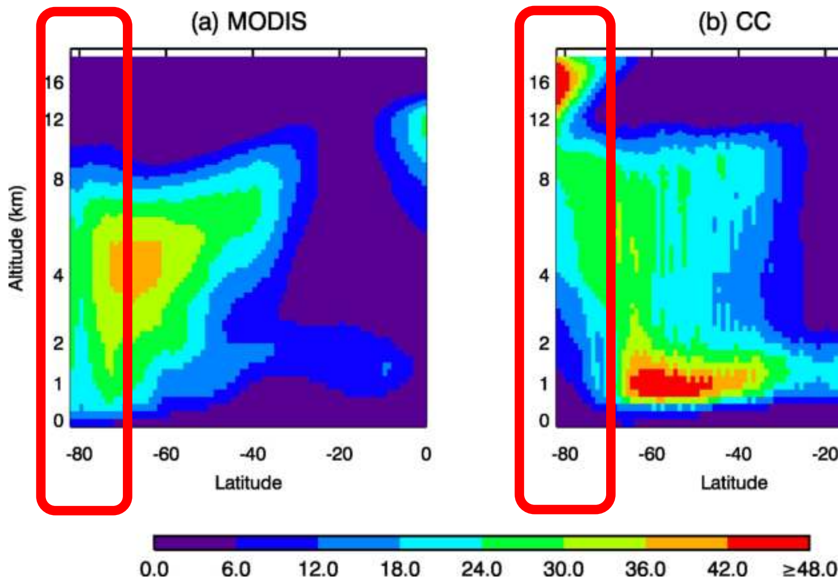
"MODIS-estimated IR emission"

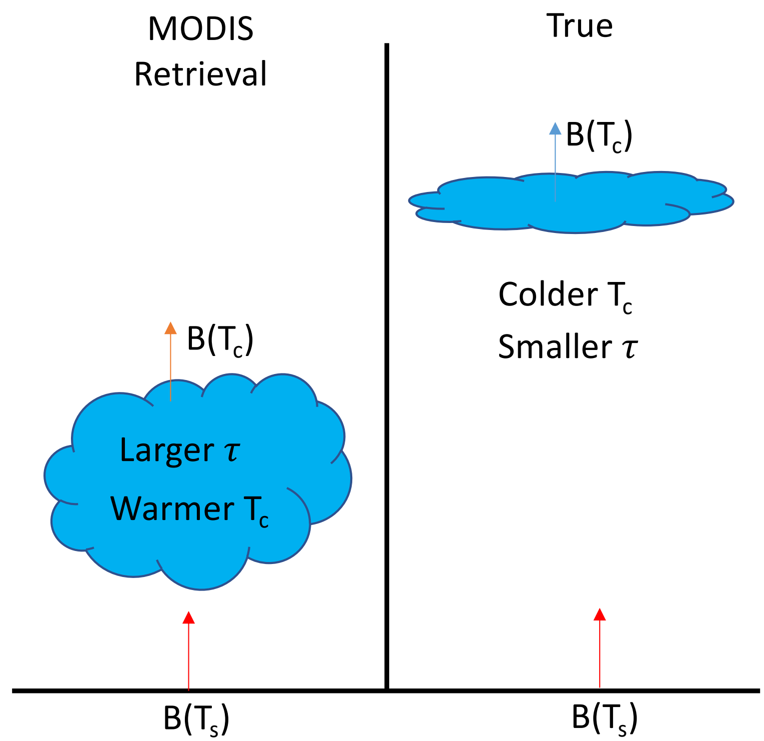
$$= \varepsilon_{11} B(T_{skin}) \exp\left(-\alpha \sum_{i=1}^{n} k_{CCM}(i)\Delta z_i\right) + \sum_{i=1}^{n} \left\{ (1 - \exp(-\alpha\, k_{CCM}(i)\Delta z_i)) B(T_i) \exp\left[ -\sum_{j=i+1}^{n} \alpha\, k_{CCM}(i)\Delta z_i \right] \right\}$$

$\alpha$ is a scaling factor to reproduce MODIS-equivalent IR emission from the merged extinction profile ($k_{CCM}(i)$).

# Nighttime MODIS Algorithm over the Antarctica

Nighttime Cloud Volume (July 2008)




- Over the Antarctica, nighttime MODIS algorithm often detects lower clouds (0-8 km) than CC (> 12 km).

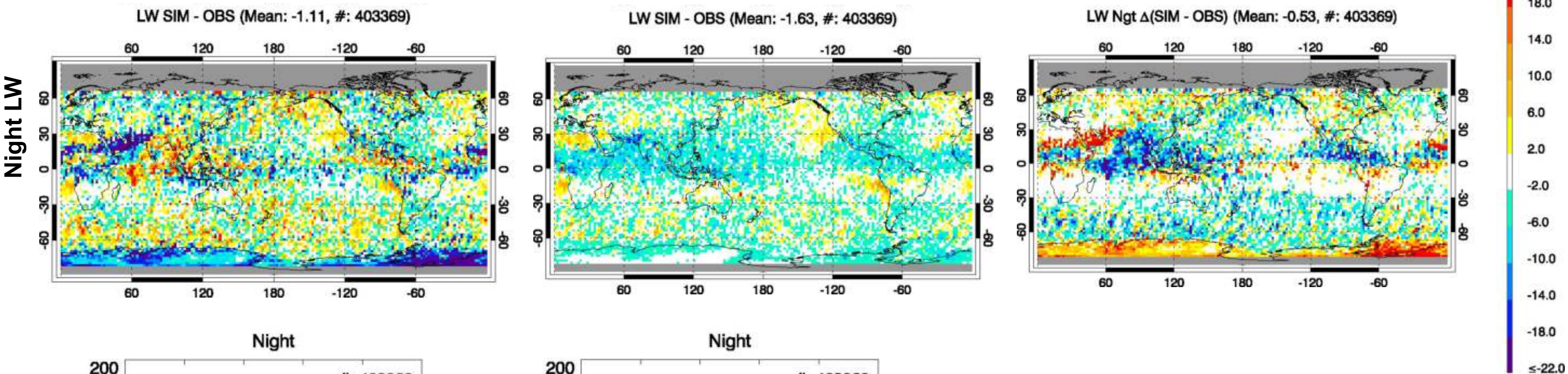
$$R_{IR} = \varepsilon_s B(T_s)\exp(-\tau_c) + B(T_c)(1-\exp(-\tau_c))$$

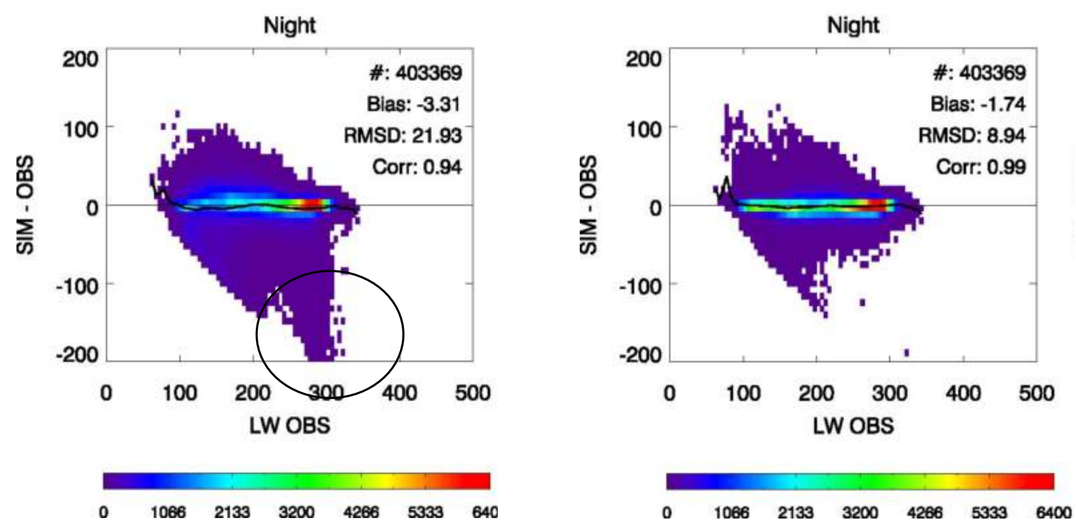
Warm biased    Positively biased

- In the IR cloud algorithm, cloud optical depth and cloud effective temperature are balanced to reproduce IR channel radiance. Therefore, low-biased cloud height (or warm-biased cloud effective temperature; $T_c$) means overestimated cloud optical depth.

# Impact of The New IR Constraining Method for SZA > 82°

**Sim – Obs [Without IR Constraining]** | **Sim – Obs [With IR Constraining]** | **[With] –[Without IR Cons]**



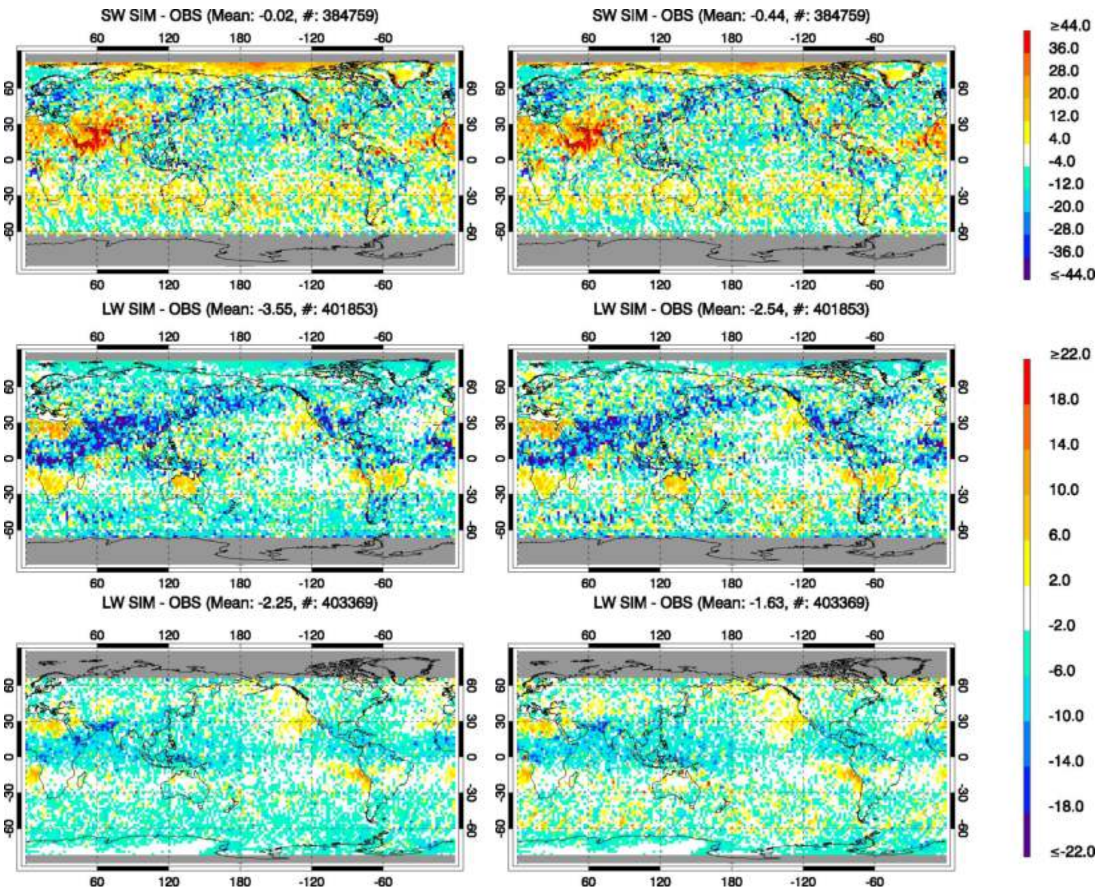




- By applying the new IR constraining method, large negative LW biases at nighttime are significantly reduced.

# Impact of Brining 2C-ICE in CCCM Flux Algorithm (With 2CICE – Without 2CICE)

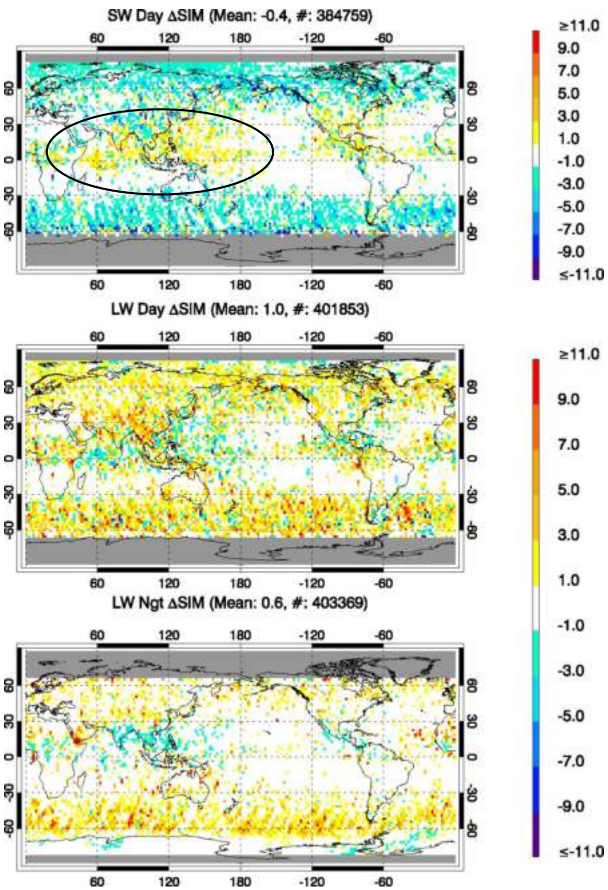
**Sim – Obs**
**[Without 2C-ICE]**

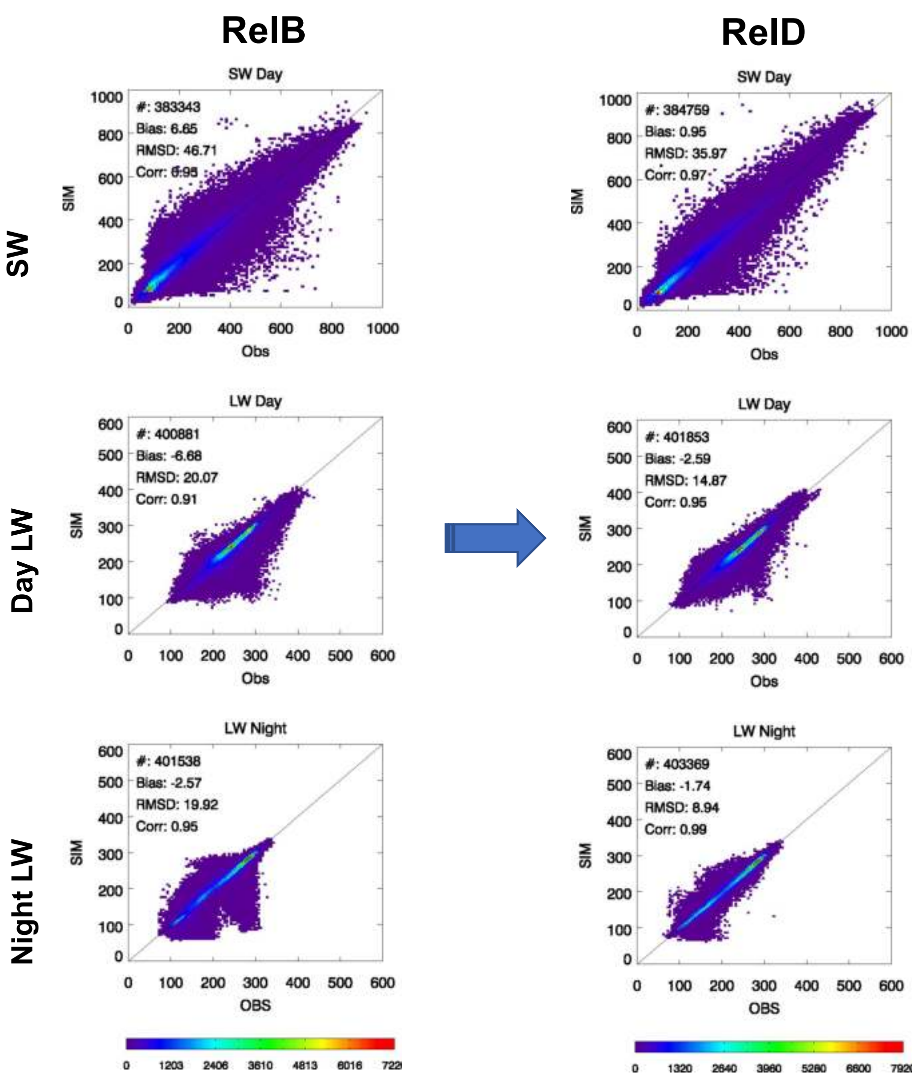
**Sim – Obs**
**[With 2C-ICE]**




Given the same phase, smaller particle cause larger SW fluxes, even with the same scaled optical depth.

**[With 2C-ICE] – [Without 2C-ICE]**






# Summary

- Compared to RelB, simulated fluxes in RelD show better agreement with CERES-derived fluxes. Specifically, the positive SW biases shown in RelB are largely decreased in RelD. This is because 1) CERES-derived SW fluxes are increased by 5.4 W m$^{-2}$, and 2) simulated SW fluxes are decreased by 2.3 W m$^{-2}$ in RelD.
- Daytime simulated LW fluxes are increased by 5 W m$^{-2}$ and it results in better agreement with observations.
- New IR constraining method improves nighttime negative LW biases over the Antarctica.